

LEPTON OSCILLATIONS

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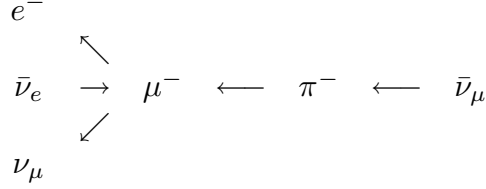
ABSTRACT

A simple but general proof is presented to show that Lorentz covariance and 4-momentum conservation alone are sufficient to obtain muon oscillations in pion decay if the recoiling neutrinos oscillate.

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π^- and μ^- Decays:

The purpose of this short note is to show that it is impossible to find a π^- momentum amplitude in the reaction $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$, which yields a neutrino space-time oscillation without also yielding a space-time oscillation in the $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$ secondary vertex provided Lorentz invariance and four-momentum conservation are strictly maintained. The proof goes as follows. Consider the double decay process



in the π^- rest frame. Energy and momentum conditions read

$$\mathbf{P}_{total}|\pi^- \rangle = \mathbf{0}, \quad H_{total}|\pi^- \rangle = M_\pi c^2 |\pi^- \rangle.$$

Thus for the outgoing space-time wave function (discrete quantum numbers implicit) defined as

$$\Psi(\mathbf{r}_\mu, t_\mu; \mathbf{r}_\nu, t_\nu) = \langle \mathbf{r}_\mu, t_\mu; \mathbf{r}_\nu, t_\nu | \pi^- \rangle,$$

energy and momentum conservation give

$$-i\hbar(\nabla_\mu + \nabla_\nu)\Psi(\mathbf{r}_\mu, t_\mu; \mathbf{r}_\nu, t_\nu) = \mathbf{0},$$

and

$$i\hbar\{(\partial/\partial t_\mu) + (\partial/\partial t_\nu)\}\Psi(\mathbf{r}_\mu, t_\mu; \mathbf{r}_\nu, t_\nu) = M_\pi c^2 \Psi(\mathbf{r}_\mu, t_\mu; \mathbf{r}_\nu, t_\nu).$$

The general solution with conserved energy and momentum is given by

$$\Psi(\mathbf{r}_\mu, t_\mu; \mathbf{r}_\nu, t_\nu) = \exp\{-i(M_\pi c^2/2\hbar)(t_\mu + t_\nu)\}\psi(\mathbf{r}_\mu - \mathbf{r}_\nu, t_\mu - t_\nu).$$

If $\psi(\mathbf{r}_\mu - \mathbf{r}_\nu, t_\mu - t_\nu)$ oscillates in (\mathbf{r}_ν, t_ν) , then it also oscillates in (\mathbf{r}_μ, t_μ) .

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